UNIVERSITY OF ILLINOIS

GRADUATE STUDY AND RESEARCH IN Mechanical Engineering

CONTENTS

FOREWORD

The Department of Mechanical Engineering offers advanced study and professional training in the general fields of power, design, and production.

Graduate study presupposes maturity of outlook. Progress is judged not only by the accumulation of units of credit but also by evidence of intellectual growth and achievement. The following criteria may be considered as evidence of maturity:

a. Display of initiative in outlining work, examining literature, developing equipment, obtaining data, and preparing reports.

b. Ability to do independent work and to present orally and in written form the results of investigations.

This booklet contains extracts from the *Graduate College Announcement* and certain other information pertaining to graduate study, fellowships, teaching assistantships, and research assistantships available to mechanical engineering graduates who wish to pursue graduate study and research. Information is included also on graduate courses offered by the Department of Mechanical Engineering.

The courses now offered in mechanical engineering cover the subject matter for which there is the greatest demand and for which staff members and facilities are at present available. Although the courses are planned to develop the competence of the student in a chosen subdivision of mechanical engineering, he has considerable freedom of choice. With the approval of his adviser, he may take courses in more than one field of mechanical engineering, or in other branches of engineering, mathematics, or the sciences.

Additional information may be obtained from the Head of the Department of Mechanical Engineering, Mechanical Engineering Building, Urbana, Illinois. For a complete statement of the regulations of the Graduate College, students should consult the *Graduate College Announcement,* copies of which may be obtained from the Graduate College, 109 Administration Building, Urbana.

GRADUATE STAFF ADVISERS

The following members of the Mechanical Engineering Faculty serve also as thesis advisers:

Norman Alwyn Parker, M.S., M.E.
Professor of Mechanical Engineering and Head of the Department

William Nelson Espy, M.S.
Professor of Mechanical Engineering

Julian Robert Fellows, M.S.
Professor of Mechanical Engineering

George William Harper, Met.E., M.S.
Associate Professor of Mechanical Engineering

William Lavaldin Hull, M.S., M.E.
Professor of Mechanical Engineering

Seichi Konzo, M.S.
Professor of Mechanical Engineering

Helmut Hans Korst, Dr.Tech.Sci.
Professor of Mechanical Engineering

Reinhold Fridtjof Larson, Ph.D.
Professor of Mechanical Engineering

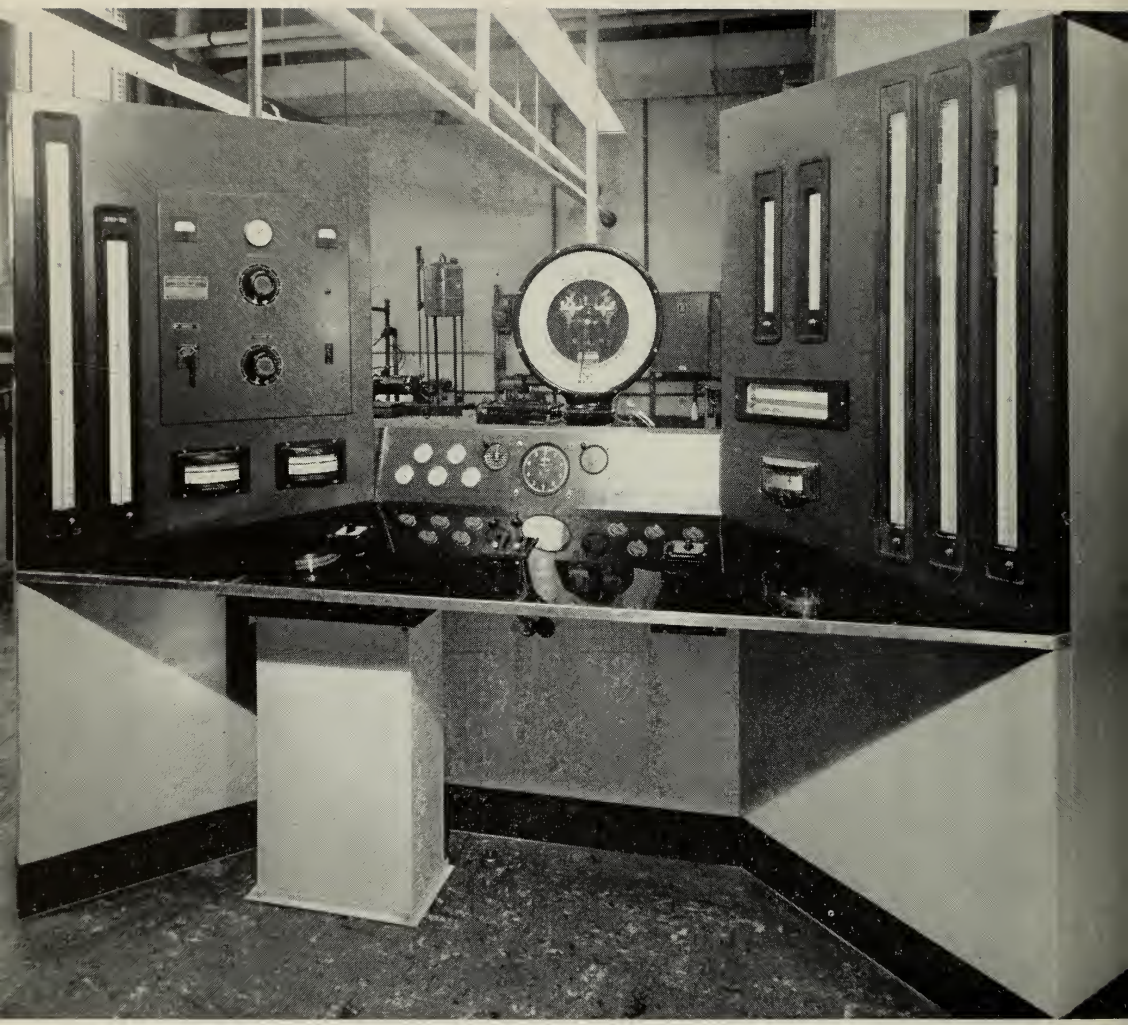
Ross J. Martin, M.S.
Associate Professor of Mechanical Engineering
Associate Director of the Engineering Experiment Station

James Harry Potter, M.E., D.Eng.
Professor of Mechanical Engineering
Chairman of the Graduate Committee

David Gerald Ryan, M.S., M.E.
Professor of Mechanical Engineering

Herman John Schrader, M.S.
Research Professor of Theoretical and Applied Mechanics
(cooperating in the Department of Mechanical Engineering)

Kenneth James Trigger, M.S., M.E.
Professor of Mechanical Engineering



ENGINE TEST PANEL

Control panel and dynamometer scale in the engine research room of the internal combustion engine laboratory. Carburetor air temperature variable from 50° F. to 150° F.; altitude control from 1,000 feet to 20,000 feet.

GRADUATE COLLEGE REQUIREMENTS

ADMISSION

Admission to the Graduate College may be granted to graduates of institutions whose requirements for the bachelor's degree in mechanical engineering are substantially equivalent to those of the University of Illinois and to applicants from other institutions approved by the Executive Faculty.

Admission to graduate courses may be granted only to those who have had the requisite undergraduate work for those courses. Students whose preparation is considered inadequate may be required to take without credit certain undergraduate courses. A student of mature age who satisfies the Dean of the Graduate College and the Department of Mechanical Engineering of his ability to pursue graduate work in a given field may be enrolled in certain graduate courses, without reference to a degree, and with the approval of the department and Graduate College be permitted to carry on desired work under the direction of the department.

Application blanks for admission may be obtained from the Director of Admissions and Records of the University, 100a Administration Building. Each applicant must submit with his application for admission an official transcript of his college record.

BASIS OF CREDIT

Credit for graduate work is counted in units. A unit course requires approximately ten hours of time each week through one semester, irrespective of the distribution of that time in class work, laboratory or field work, or private study. Four such courses constitute a student's normal program for one semester.

THE DEGREE OF MASTER OF SCIENCE

Amount of Work Required. Candidates for the degree of Master of Science in Mechanical Engineering are required to do at least one full year's work in residence, or its equivalent, including a thesis. The requirement of a thesis may be waived in exceptional cases. Four to five units constitute a normal semester program for the master's degree. A minimum of eight units must be completed for the degree when a thesis is included. A minimum of nine units is required if a thesis is not included. Only students with high scholastic standing are permitted to complete their graduate studies with these minimum programs.

Majors and Minors. A candidate for a master's degree may do all his work in one subject, or he may select a major and one minor, or a major and two minors. A major or minor denotes the field of knowledge of a department, or such part thereof as constitutes a separate and independent division of that field. For a master's degree a major is at least one-half of the work, or a minimum of four units, for one year. Less than one unit may not be counted as satisfying the requirements of a minor without the approval of the department.

Master's Theses. Each candidate for a master's degree, with the exception noted above, is required to present two copies of a thesis on some subject approved by the professor in charge of his major work. The thesis will ordinarily demand from one to two units of work.

THE DEGREE OF DOCTOR OF PHILOSOPHY

The degree of Doctor of Philosophy is offered in certain fields of engineering science. This degree is based upon training in academic and experimental fields, and is intended as a recognition of the candidate's ability to undertake original work. Possession of a master's degree does not necessarily admit a man to candidacy for the higher degree.

Selection for doctoral candidacy is based upon performance in graduate courses, laboratories, and seminars. Ability in academic work is necessary but not sufficient; the student must give evidence of facility in experimental methods and in the analysis of information obtained in the laboratory. This second requirement is based upon performance in the various courses in Laboratory Investigations, or in the execution of an experimental thesis at the master's level.

The general requirements for this degree, as to preliminary education, foreign language attainments, etc., are given in the *Graduate College Announcement.*

A student in mechanical engineering who desires to become a candidate for the degree of Doctor of Philosophy in Engineering is required to pursue a major subject in the department. He is also required to choose one minor subject, or he may choose two. If one minor only is chosen it must be taken in a department of study other than that of the major, and credit for it may be earned by work representing not less than four units, or one-sixth of the total residence required for the doctorate. If two minors are chosen, one must be a subject closely related to the major. With the approval of the adviser and the Dean it may be a division of the major field of study. The other minor (not less than two units) must, in that case, be taken in a department of study other than that of the major.

BUILDINGS AND EQUIPMENT

The teaching and research activities of the Department of Mechanical Engineering are conducted largely in the Mechanical Engineering Building, the Mechanical Engineering Laboratory, the Foundry, the Research Residences, and at the University Airport.

MECHANICAL ENGINEERING BUILDING

This building houses the machine design facilities and many of the teaching and research laboratories. A large machine shop is supplemented by laboratories in welding, machine tool research, time and motion study, and precision measuring devices. A complete heat treating laboratory is backed by metallographic and strength-testing facilities.

A new and well-equipped internal combustion laboratory is divided into teaching and research sections, with four special test cells for graduate student work.

The basement laboratories house facilities for fuels and combustion research and for work in the fields of heat transfer, thermodynamics, and process controlling devices. A separate machine shop is provided for the construction of research equipment.

MECHANICAL ENGINEERING LABORATORY

This laboratory houses the steam power, heavy duty internal combustion engine, heating, ventilating, air conditioning, and refrigeration equipment used in the testing and associated experimental work in mechanical engineering. The physical environment laboratory is also located here.

FOUNDRY

A separate building is provided for the pattern design room and foundry. Facilities are provided for nonferrous casting, including aluminum, brass, and bronze, and for cast iron.

UNIVERSITY AIRPORT

Facilities are available for experiments on the high velocity flow of air. Certain wind tunnel equipment is being developed in concert with other departments.

RESEARCH RESIDENCES

Practical test information on house heating and allied problems is obtained in actual dwellings. Three research residences and a floor slab laboratory are available for such studies.

OTHER FACILITIES

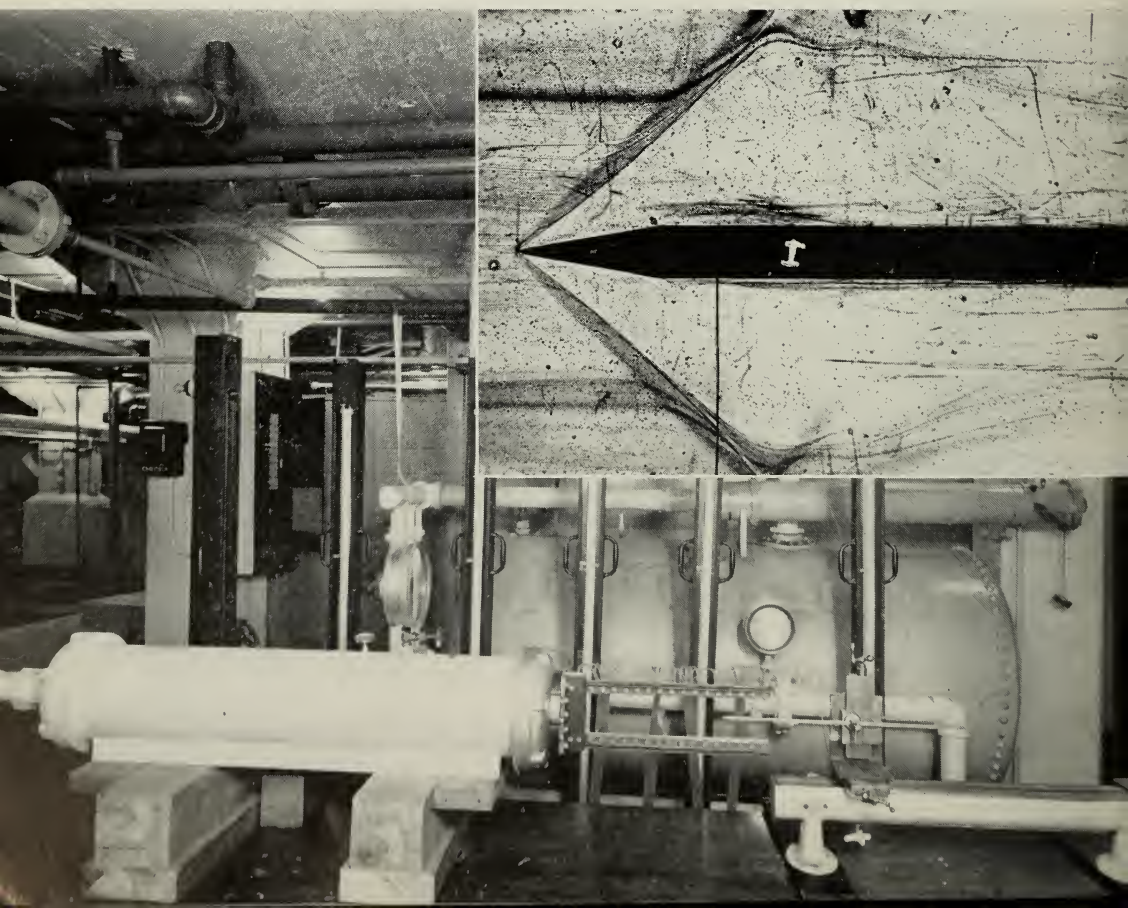
Graduate students in mechanical engineering frequently elect courses which make use of the laboratories of the Department of Theoretical and Applied Mechanics which are located in Talbot Laboratory. This laboratory is well equipped with facilities for research work in subjects closely related to the work in machine design and fluid flow.

ENGINEERING LIBRARY

The Engineering Library provides unusual facilities for students pursuing advanced work. This library, located in Civil Engineering Hall, contains 64,350 volumes, including books, bound volumes of magazines, and publications of engineering societies. More than 550 technical magazines and publications of engineering societies are currently received. It includes an excellent collection of general technical dictionaries in several foreign languages with definitions in English, as well as similar dictionaries in special fields of engineering.

HIGH-VELOCITY AIR FLOW RESEARCH

Two-dimensional air flow channel with transparent walls, showing pressure taps and probe. Inset shadowgraph shows angle shock due to probe in supersonic air stream.



FELLOWSHIPS AND ASSISTANTSHIPS

UNIVERSITY FELLOWSHIPS

A number of University Fellowships are awarded each year to graduate students of ability and promise for work toward a master's or doctor's degree. These fellowships carry exemption from tuition and all fees of the regular academic year, except the hospital and medical service fee, during the period of the fellowship. First-year fellowships carry a stipend of $800; those open to second-year and third-year graduate students carry stipends of $900 and $1,000, respectively.

Candidates for these fellowships must be graduates of the University of Illinois, or of colleges or universities having equivalent requirements for the bachelor's degree. To be eligible for a third-year fellowship, an applicant must have completed the language requirements and must have passed the preliminary oral examination no later than four weeks following the beginning of the session during which the fellowship is effective.

Application must be made on forms obtainable from the Dean of the Graduate College. These forms must reach the Dean of the Graduate College not later than February 15 of the academic year preceding that for which the fellowship is desired. Applications received later than February 15 will not be considered until after April 15, the date when appointees from the first list of applications must accept or refuse their appointments.

Nominations to fellowships are made on the grounds of worthiness of character, scholastic attainments, and promise of success in the principal line of study or research to which the candidate proposes to devote himself.

INDUSTRIAL FELLOWSHIPS

Industrial fellowships are frequently available for second-year and third-year graduate students. Information on these fellowships may be had by writing to the Department of Mechanical Engineering.

TEACHING ASSISTANTSHIPS

A number of teaching assistantships on one-half time or one-quarter time basis are available to graduate students in mechanical engineering. The stipend is $1,350 for a half-time assistant and $675 for a quarter-time assistant, for a school year of two semesters, and exemption from tuition, laboratory, library, and supply fees. A half-time assistant can

carry up to three units of graduate work each semester. It is usually possible to assign an assistant to the teaching of a course in the field of his special interest. Inquiries concerning these positions should be directed to the Head of the Department of Mechanical Engineering.

RESEARCH ASSISTANTSHIPS IN THE ENGINEERING EXPERIMENT STATION

The Engineering Experiment Station is devoted to the study of problems of special importance to engineering, and to the stimulation and elevation of engineering education. By undertaking a line of graduate study in close association with some one of the projects carried on in the Station, the student may come into contact with aspects of his specialty which he would rarely touch in a purely academic study. The Experiment Station makes available apparatus, equipment, and the services of mechanicians, which may materially facilitate the progress of investigations.

Research assistantships with a stipend of $1,350 for a school year of two semesters, and exemption from the payment of the usual tuition fee, are open to graduates of approved technical schools and universities. Applicants to whom these graduate assistantships are awarded agree to hold them for two school years, devoting one-half of their time to the work of the Engineering Experiment Station. A research assistant can carry up to three units of graduate work each semester. At the end of this period, if all requirements of the Graduate College have been met, the degree of Master of Science will be conferred.

A number of research assistantships in mechanical engineering are available. They include assistantships established by the University and others provided by cooperative research agreement with state and federal agencies, technical societies, and engineering associations. Fields of research which are now active include thermodynamics, heating, ventilating, air conditioning, refrigeration, steam power, internal combustion engines, fuel testing, flow of fluids, heat transfer, gas turbines, jet propulsion, machine design, power plant design, product design, heat treatment of metals, metal processing, time and motion study, and production methods. It is usually possible to assign a research assistant to a project in the field of his special interest. Often the research in which he is engaged will form the basis of his thesis, but his thesis is not restricted to this field.

Applications for research assistantships should be made to the Director of the Engineering Experiment Station not later than March 1.

FEES

Persons on the academic or administrative staffs of the University or allied surveys in any capacity, or who are on permanent employment on the nonacademic staff (subject to the approval of the head of their department or division), whose salaries do not exceed $2,400 for nine months appointment or $2,934 for twelve months appointment, are exempt from payment of all registration fees. Those with salaries above these maximums pay tuition and the laboratory, library, and supply fee. Holders of fellowships are exempt from all fees except the hospital and medical service fee. All other students registering for resident work pay fees each semester or summer session as follows:

SEMESTER FEES	*Regular Schedule* (*Over two units*)	*Reduced Schedule* (*Two units or less*)
Tuition Fee		
Residents of Illinois	$ 40.00	$12.00 per unit
Nonresidents of Illinois	150.00	40.00 per unit
Laboratory, Library, and Supply Fee	8.00	4.00
Hospital and Medical Service Fee. Students who present evidence of participation in any other insurance system providing the same benefits as those covered by the University fee may petition the Dean of Students for refund of this fee. Students registered for not over one unit are exempt from this fee.	5.00	5.00
Illini Union Service Charge. Students registered for not over one unit are exempt from this fee.	7.00	7.00
Late Registration Fee. Former students, whether on appointment or not, who register after the regular registration days in either semester are subject to this fee.	5.00	5.00

SUMMER SESSION FEES	*Regular Schedule* (*Over one unit*)	*Reduced Schedule* (*One unit or less*)
Tuition Fee		
Residents of Illinois	$20.00	$12.00 per unit
Nonresidents of Illinois	75.00	40.00 per unit
Laboratory, Library, and Supply Fee	4.00	2.00
Hospital and Medical Service Fee. A student registered for not over one-half unit is exempt from this fee.	2.50	2.50
Illini Union Service Charge. A student registered for not over one-half unit is exempt from this fee.	3.50	3.50

SEMESTER AND SUMMER SESSION FEES

Change of Program Fee $1.00
This fee is charged for every change slip issued later than the date shown on the Graduate College calendar.

"In Absentia"
Students enrolled for thesis work for the master's or doctor's degree on leave of absence pay the tuition fee only, as listed above.

Professional Degrees 25.00
This fee is payable by candidates for professional degrees in engineering each year.

Transcript Fee 0.50
Each student who has paid all his University fees is entitled to receive, without charge, one transcript of his record. For each additional transcript the fee is $.50.

Service Charge for Deferred Fees. A service charge of ten per cent of the amount of fees deferred, but not to exceed $3.00 a semester, is assessed for the privilege of deferring fees. If deferred fees are paid in full within ten days after registration, the service charge is refunded except that a minimum service charge of $1.00 is retained by the University in all cases. The hospital and medical service fee, the Illini Union service charge, the service charge for deferring fees, and all charges from previous semesters must be paid on the day of registration.

REGISTRATION DATES AND PROCEDURE

Registration for the first semester normally is held during the third week of September, that for the second semester during the first week of February, and in June for the summer session. A graduate student in mechanical engineering may enter at any of these times. Commencement is held in June and February, but degrees are conferred also in August and October.

The following procedure is recommended for the prospective graduate student:

a. Secure a permit to enter the Graduate College from the Director of Admissions and Records.

b. Study the requirements for advanced degrees as given in this booklet and in the *Graduate College Announcement.*

c. Prepare a tentative outline of the sequence of courses to be taken.

d. Confer with the adviser, Professor N. A. Parker, Head of the Department of Mechanical Engineering, Mechanical Engineering Building, Urbana, Illinois.

SUGGESTED PROGRAM OF GRADUATE STUDY

The program of study is flexible and is designed to accommodate the interests of the individual. The courses listed below, which include

certain courses offered by other departments, are suggestions from which a balanced program of study may be evolved. A balanced program should include offerings from all three of the following subdivisions: mathematical, theoretical and analytical, and technical or professional.

A candidate whose undergraduate credits do not include the prerequisite courses for any particular graduate study may be required to enroll without credit in such undergraduate courses at the University of Illinois.

COURSES IN MECHANICAL ENGINEERING

The graduate courses described herein will be offered subject to the requirements of minimum registration, availability of staff, and plant limitations.

The prerequisite for graduate work in mechanical engineering is the equivalent of the undergraduate courses required for the degree of Bachelor of Science in Mechanical Engineering. Courses numbered in the 300 group are those open to advanced undergraduates and graduate students, and those in the 400 group are for graduate students only. In registering for a course with variable credit, as ½ to 1½ units, each student puts on his program card the number of units for which he intends to take the course. Courses numbered in the 300 group have variable credits of ½ to ¾ unit; the ½ unit represents credit for work corresponding to advanced undergraduate study; the additional ¼ unit requires a term paper.

NOTES FOR LABORATORY INVESTIGATIONS

The following general notes apply to all graduate courses ending in 8 or 9 and designated as "Laboratory Investigations."

Selection of Topic. If the student has a specific problem that can be handled with existing or contemplated facilities and funds, such problems will be given preference. If the student has no specific problem to suggest, he may be furnished a list of projects from which a choice can be made, subject always to availability of funds, equipment, and staff.

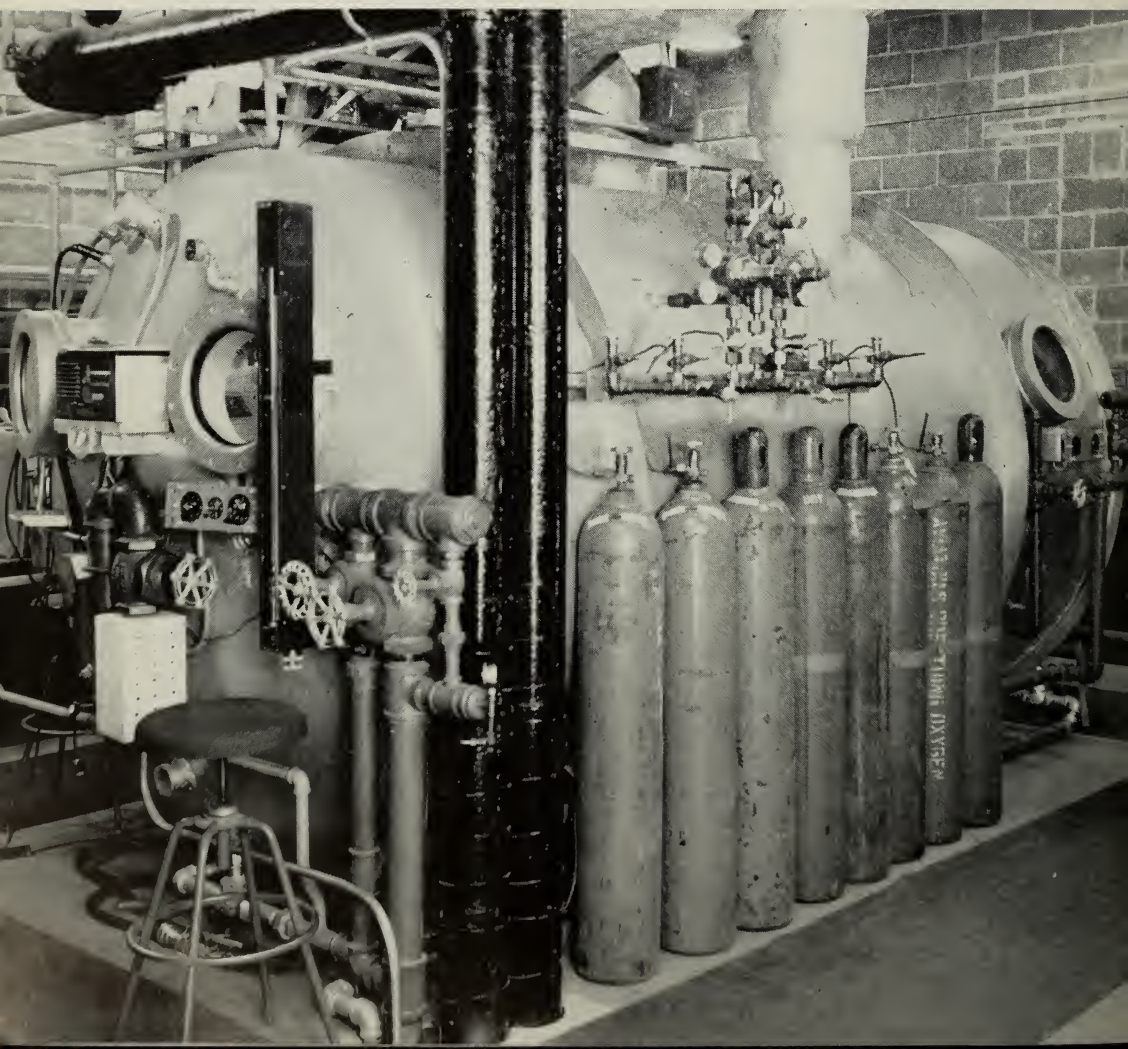
Procedure. Preliminary conferences should be arranged with the staff member in charge, and a working program outlined. This outline should include: (a) history of project; (b) importance of subject and its place in the field; (c) proposed or alternate approaches to the solution; and (d) suggested references for bibliographical survey with

instructions as to type of abstracts desired and method of indexing same.

Projects. In general, projects which satisfy any or all of the following requirements should be considered: (a) studies of methods of testing, or development of instrumentation; (b) exploratory research of unknown or controversial items; (c) investigations of physical constants; and (d) investigations which may border on routine or repetitive work, but which may acquaint the student with a number of fundamental measurements and analyses. Although the courses are

PHYSICAL ENVIRONMENT TEST UNIT

The environmental factors of temperature, pressure, and humidity may be varied over wide ranges in this specially constructed chamber. The physiological and psychological effects of these variables upon both animal and human subjects are studied.



entitled "Laboratory Investigations," part or all of the work may be of analytical nature.

Maximum Credits. Except under unusual circumstances the maximum number of credits which will be permitted in any course ending in 8 or 9 will be three units toward the requirements for a master's degree. An additional four units of credit will be permitted for candidates working toward a doctor's degree. In most cases the research work conducted in these laboratory investigations can be reported in the thesis submitted for fulfillment of the requirements for each degree.

COURSES FOR GRADUATES AND ADVANCED UNDERGRADUATES

301. Engineering Thermodynamics. ½ to ¾ unit; three one-hour periods a week; first semester. *Prerequisite:* Undergraduate courses in Thermodynamics and Heat Engines. Espy.

Application of principles of thermodynamics to engineering processes with special attention to steady flow of a compressible medium in insulated or non-insulated ducts, availability of thermal energy, heat and power from combustion, methods of formulation and correlation of properties of a pure substance, and effect of equilibrium on the analysis of internal combustion engines and cycles.

303. Fuels and Combustion. ½ to ¾ unit; two two-hour periods a week; first semester. *Prerequisite:* Undergraduate courses in Chemistry and Thermodynamics. Fellows.

Fuel resources; composition of natural and manufactured fuels; fuel calorimeters; comparison of fuels from an economic standpoint; combustion stoichiometry; molal heat capacities; adiabatic combustion temperature; coal, oil, and gas burners; smoke abatement.

305. Thermodynamics of High Velocity Flow. ½ to ¾ unit; three one-hour periods a week; first or second semester. *Prerequisite:* Undergraduate courses in Thermodynamics and Heat Engines and/or consent of instructor. Zubko, Page.

The thermodynamics of gases in high-velocity flow within enclosed channels using Mach number as the fundamental variable; analyses of the basic flow equations; effects of friction and plane shock theory; application to thermodynamic cycles involving nozzles, diffusers, compressors, and turbines.

311. Instrumentation and Measurements. ½ to ¾ unit; three one-hour periods a week; first and second semester. *Prerequisite:* Undergraduate courses in Mechanical Engineering Laboratory. Konzo.

Instruments and measuring equipment for flow, temperature, pressure, speed, and gas analysis. Topics include theory and characteristics of a number of instruments used in research, development, and production; flow measurements of low pressure gases and liquids by Pitot tube, Thomas meter, orifices, nozzles, anemometers, Venturi meters, hot-wire anemometers, heated thermocouple anemometers, and displacement rotameters;

temperature measurements by thermocouples, resistance thermometers, and pyrometers; hot-plate and hot-box conductivity meters; humidity and dew-point instruments, manometers; indicating and recording devices; special topics.

314. Lubrication. ½ to ¾ unit; two one-hour periods and one three-hour period a week; first semester. *Prerequisite:* Undergraduate courses in Machine Design and Fluid Mechanics.

The theories of lubrication; manufacture and properties of lubricants; methods of testing; lubrication methods and appliances. A study of the lubrication requirements of machines of many kinds. Topics include fluid friction and viscosity; boundary lubrication; thin film lubrication and oiliness; hydrodynamic theory of lubrication; extreme pressure lubricants; thermal equilibrium, bearing loads, and design practices; ball, roller, and needle bearings; comparison of rolling-contact bearings with plain bearings.

332. Theory of Internal Combustion Engines. ½ to ¾ unit; three one-hour periods a week; second semester. *Prerequisite:* Undergraduate courses in Internal Combustion Engines. HULL.

Study of thermodynamics of reciprocating engine cycles, considering such factors as chemical dissociation, heat loss, combustion chamber shape, and flow through valves and manifolds. Topics include theoretical engine cycles and deviations of actual cycles from the theoretical; actual cycle analysis by computation and by chart; determination of heat loss during various stages of cycle; effects of compression ratio, manifold pressure, and exhaust pressure; study of valves, ports, manifolds, and mixture distribution, considering flow conditions.

350 (I.E.). Tool Engineering Analysis. ½ to ¾ unit; three one-hour periods a week; second semester. *Prerequisite:* Undergraduate course in Tool Engineering. DOYLE.

Advanced problems in tool engineering. Analysis and solution of problems by analytical methods with special attention to dimensional planning and economic lot size. Design of tools for metal forming and shearing.

358 (I.E.). Problems in Industrial Safety. ½ to ¾ unit; three one-hour periods a week; first or second semester. *Prerequisite:* Undergraduate course in Industrial Safety. HARPER.

Detailed study of the principles of industrial (and related) accident prevention and their application. Course is designed to provide a sound working knowledge of safety principles for students interested in entering the field of safety engineering in industry. Topics include development of industrial safety movement including accident costs, accident sources and causes, and responsibility of management; appraising safety performance by safety inspection, job safety analysis, and accident investigation; planning and arranging for safety in production engineering; training, supervision, and organizations; industrial hygiene; common hazards including explosions, fires, fumes, and electrical devices; special investigations.

361. Railway Motive Power Equipment. ½ to ¾ unit; two two-hour periods a week; first semester. *Prerequisite:* Senior standing in Mechanical Engineering. SCHRADER.

A technical study of the various types of motive power used on rail-

ways with special emphasis on steam, Diesel, and electric locomotives, and secondary consideration to special types such as the steam turbine, turbo-electric, and gas turbine locomotives. Topics include primary considerations in design and locomotive ratios; economics, original costs, maintenance, availability, and effect on roadbed; general problems in design rather than of detailed parts; thermodynamics of various types, weight distribution, and locomotive design ratios; legal considerations, Interstate Commerce rules and regulations; manufacturers' standards and specifications.

362. Railway Motive Power Operation. ½ to ¾ unit; two two-hour periods a week; second semester. *Prerequisite:* Senior standing in Mechanical Engineering. SCHRADER.

A study of the conditions under which railway motive power operates. Economics of operation, present equipment, proposed new equipment, servicing and maintenance, availability; train resistance, motive power, tractive force, speed, time and distance curves, preparation of timetables; problems in stopping trains; terminal and repair facilities.

371. Petroleum Production Engineering — Field Development. ½ to ¾ unit; three one-hour periods a week; first semester. *Prerequisite:* Senior standing. LARSON.

Properties of petroleum, oil reservoirs, exploration and drilling methods, casing methods, and well logging.

372. Petroleum Production Engineering — Field Production and Exploitation. ½ to ¾ unit; three one-hour periods a week; second semester. *Prerequisite:* Mechanical Engineering 371. LARSON.

Study of reservoir performance, principle of oil and gas recovery, storage and transportation, and economics of oil field exploitation.

COURSES FOR GRADUATES

401. Thermodynamics. 1 unit; three one-hour periods a week; first semester. *Prerequisite:* One year course in Thermodynamics. ESPY.

Application of thermodynamics to the analysis and solution of engineering problems involving energy transfer and conversion. Topics include development of general thermodynamic equations and identities; development of modern methods for analysis of thermodynamic processes; methods of formulation and correlation of properties of working media from experimental data; thermodynamic analysis of flow of compressible media at high speeds.

402. Thermodynamics of Gaseous Equilibrium. 1 unit; two two-hour periods a week; second semester. *Prerequisite:* Mechanical Engineering 301 or 401. ESPY.

Application of thermodynamics to analysis of combustion of gases used as working media in power production. Topics include equilibrium as applied to problems of power production; chemical equilibrium as applied to gaseous systems; calculations of equilibrium composition and temperatures; analysis of effect of equilibrium on internal combustion engine cycles; review of literature for application to power field.

403. Advanced Combustion. 1 unit; three one-hour periods and one three-hour laboratory period a week; first semester. *Prerequisite:* Undergraduate courses in Thermodynamics and Differential Equations. POTTER.

A study of the theories of combustion and of combustion measurements in engineering structures. Variable specific heats; heats of combustion; kinetics of combustion reactions; adiabatic flame temperatures; experimental flame temperature techniques; ignition and inflammability limits of fuels; flame velocities; explosions.

404. Gas Dynamics. 1 unit; two two-hour periods a week; first semester. *Prerequisite:* Undergraduate courses in Thermodynamics, Fluid Mechanics, and Differential Equations. KORST.

Introduction to theoretical gas dynamics. Properties of compressible real fluids. Fundamental laws and basic equations for subsonic and supersonic steady and unsteady motion; interpretation and use in one- and multi-dimensional problems.

405. Heat Transfer. 1 unit; three one-hour periods a week; second semester. *Prerequisite:* Undergraduate courses in Heat Transfer. LARSON, CHAO.

Analysis of the methods and mechanisms of heat transfer, dimensional analysis method, design of heat exchangers, transient state heat transfer. Special problems in insulation and heat transfer. Topics include steady-state heat conduction, linear and two dimensional; Fourier's general equation; transient heat conduction; radiation exchange; radiation through and from gases; film theory; method of dimensional analysis; forced and natural convection equations; boiling liquids and condensing vapors; over-all heat transfer; fluid pressure losses.

406. Heat Conduction in Solids. 1 unit; three one-hour periods a week; first semester. *Prerequisite:* Undergraduate courses in Heat Transfer and Differential Equations. CHAO.

Fundamentals; general differential equation of heat conduction; methods of solution; steady-state heat flow; transient heat flow, one and two dimensions; periodic flow of heat; internal heat source in solids.

407. Selected Topics in Gas Dynamics. 1 unit; three one-hour periods a week plus individual laboratory assignments; second semester. *Prerequisite:* Mechanical Engineering 404. KORST.

Theoretical analyses of non-steady processes including scavenging, pulse jet, shock tube, and the comprex. The course includes an introduction to high velocity laboratory techniques.

408. Laboratory Investigations in Thermodynamics. ½ to 1½ units; one or more semesters; time to be arranged; first and second semesters. *Prerequisite:* Undergraduate courses in Thermodynamics and Mechanical Engineering Laboratory. STAFF.

Special investigations involving thermodynamic analysis, thermodynamic properties, and performances of physical and chemical systems. (See general notes on page 13.)

409. Laboratory Investigations in Fluid Flow, Heat Transfer, and Combustion. ½ to 1½ units; one or more semesters; time to be arranged; first and second semesters. *Prerequisite:* Undergraduate courses in Thermodynamics or Fluid Mechanics. Members of the staff.

Special investigations in flow, metering, heat transfer, heat exchanger design and performance, and combustion. (See general notes on page 13.)

413. Industrial Control Systems. ½ unit; two two-hour periods a

week; second semester. *Prerequisite:* Mechanical Engineering 311 or equivalent. McCLAY.

Study of basic elements of process control systems and process characteristics, particularly of thermal and mechanical processes. Topics include process characteristics including capacity, transfer, and dead time; measuring devices and their characteristics; automatic control devices which include single speed, proportional speed, and proportional position action with the application of reset and rate response to the latter.

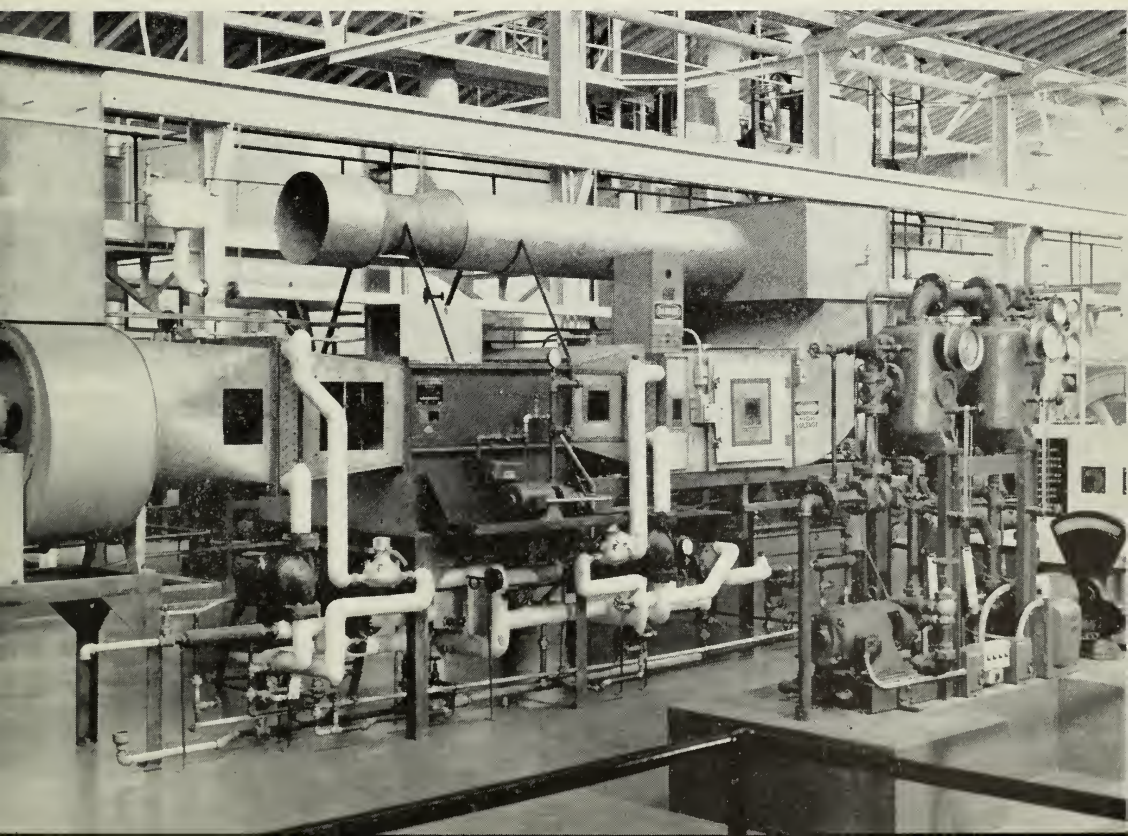
421. Heating and Air Conditioning. 1 unit; two two-hour periods a week; first semester. *Prerequisite:* Undergraduate courses in Heating, Ventilating, and Air Conditioning. KONZO, FELLOWS.

Advanced study of heating, ventilating, and air conditioning; factors

STEAM JET REFRIGERATION UNIT AND LABORATORY AIR CONDITIONING UNIT

Right Foreground: Experimental steam jet refrigeration unit used for demonstration purposes and for determining capacity and steam consumption at various operating conditions.

Center: Assembly of air conditioning equipment consisting of capillary air washer, complete with preheat and reheat coils, affording three separate means of air humidification. A special feature of the unit is a dry type electronic precipitator. Both units are fully instrumented for research work.



affecting heat loss and heat gain of buildings, physiological effects of environment, equipment design of heat transfer equipment. Individual problems. Topics include test methods and current research; climate in relation to health and comfort; structural components of buildings as related to heat gain, heat loss, solar orientation, and vapor transmission; human response to environment; ventilation requirements for health and safety; combustion and heat transfer including test methods for fuel burning devices, venting requirements, and heat transfer factors; heat transfer as applied to problems in the field.

422. Heating and Air Conditioning Design. 1 unit; two two-hour periods a week; second semester. *Prerequisite:* Mechanical Engineering 421. Konzo, Fellows.

Factors affecting design of steam, hot water, and air systems, including pipe and duct design, heat transfer rates, and control of equipment. Special topics such as panel heating, electrical heating, radiant heating, reverse cycle refrigeration. Topics include volume and temperature requirements, fan performance characteristics, resistance of fittings, and auxiliary equipment for air systems; flow through pipes, resistance of fittings, and pump characteristics for water systems; flow characteristics of steam systems; elements of automatic controls for heating and air conditioning.

423. Refrigeration Theory and Application. 1 unit; two two-hour periods a week; second semester. *Prerequisite:* Undergraduate course in Refrigeration. Martin.

Advanced study of processes and cycles; design problem; and special applications. Topics include thermodynamic aspects of compression cycles, properties of refrigerants, and performance calculations; air conditioning principles and psychrometric analysis of air mixtures; design of cold storage plant including heat gain, construction, selection of equipment, and plant layout; refrigeration processes including absorption, adsorption, stage compression, dual compression, dual refrigerants, steam jet, and centrifugal compression; term paper.

428. Laboratory Investigations in Refrigeration. ½ to 1½ units; one or more semesters; time to be arranged; first and second semesters. *Prerequisite:* Undergraduate courses in Refrigeration and Mechanical Engineering Laboratory. Martin.

Special investigations in refrigeration. (See general notes on page 13.)

429. Laboratory Investigations in Heating and Air Conditioning. ½ to 1½ units; one or more semesters; time to be arranged; first and second semesters. *Prerequisite:* Undergraduate courses in Heating and Mechanical Engineering Laboratory. Staff.

Special investigations in heating, ventilating, and air conditioning. (Note: Research projects sponsored by the Engineering Experiment Station include two or more heating research residences, as well as numerous laboratory investigations. A limited number of students can be assigned to specific phases of these cooperative research projects. See general notes on page 13.)

431. Gas Turbines and Reaction Machines. 1 unit; two two-hour periods a week; second semester. *Prerequisite:* Undergraduate courses in

Thermodynamics, Power Plant Equipment, and Mechanical Engineering Laboratory. LARSON.

Analysis of gas turbine cycles, media, combustion, construction and operation, impulse and reaction machinery; heat exchange and insulation. Topics include internal combustion gas turbine cycles; limitations and practicability; open cycle calculations; ideal and actual gases; compression ratios; regeneration; isothermal cycle; water injection; fuels and combustors; compressor and turbine blade dynamics and characteristics; cycle performance; closed cycles and special media; supercharging; structural and metallurgical problems.

432. Theory of Rotary Compressors. 1 unit; two two-hour periods a week; second semester. *Prerequisite:* Undergraduate courses in Thermodynamics and Fluid Mechanics. KORST.

Thermodynamical and mechanical fundamentals, compression with and without cooling, classification of compressors, similarity considerations and operating characteristics, principles of and computations for radial compressors, improvement in performance of integrating parts; axial flow compressors; lattice and airfoil theory; change in operating conditions of turbo-compressors; regulation; rotary positive blowers.

433. Prime Movers. 1 unit; two one-hour periods and one three-hour computation period a week; second semester. *Prerequisite:* Undergraduate courses in Thermodynamics and Heat Engines. POTTER.

Steam and diesel engines, and steam, gas, and hydraulic turbines as power prime movers. Detailed analysis of flow and internal losses in steam and hydraulic turbines. Basic design and performance considerations in central station prime movers.

438. Laboratory Investigations in Power Machinery. ½ to 1½ units; one or more semesters; time to be arranged; first and second semesters. *Prerequisite:* Undergraduate course in Mechanical Engineering Laboratory. STAFF.

Special investigations in power machinery, such as turbines, engines, fans, and compressors. In the operation of some of the equipment, two or more students may be required. (See general notes on page 13.)

441. Machine Design. 1 unit; three two-hour periods a week; first semester. *Prerequisite:* Undergraduate courses in Machine Design and Mechanics of Machinery. RYAN.

A technical application course designed to focus the previously acquired design experiences on the creative problem of developing machines to perform specified functions; proper consideration of manufacturing processes involved; checking of all parts for stress, wear, vibration, fatigue, etc. Topics include new developments in strength of materials; application of manufacturing standards, study of lubrication methods, safety requirements, appearance, and costs; design of a machine that will involve investigation of specific problems to illustrate methods of analysis and development of their solutions.

442. Product Design. 1 unit; three two-hour periods a week; second semester. *Prerequisite:* Undergraduate courses in Machine Design and Production Engineering.

A detailed analysis of the various constituent mechanisms and appa-

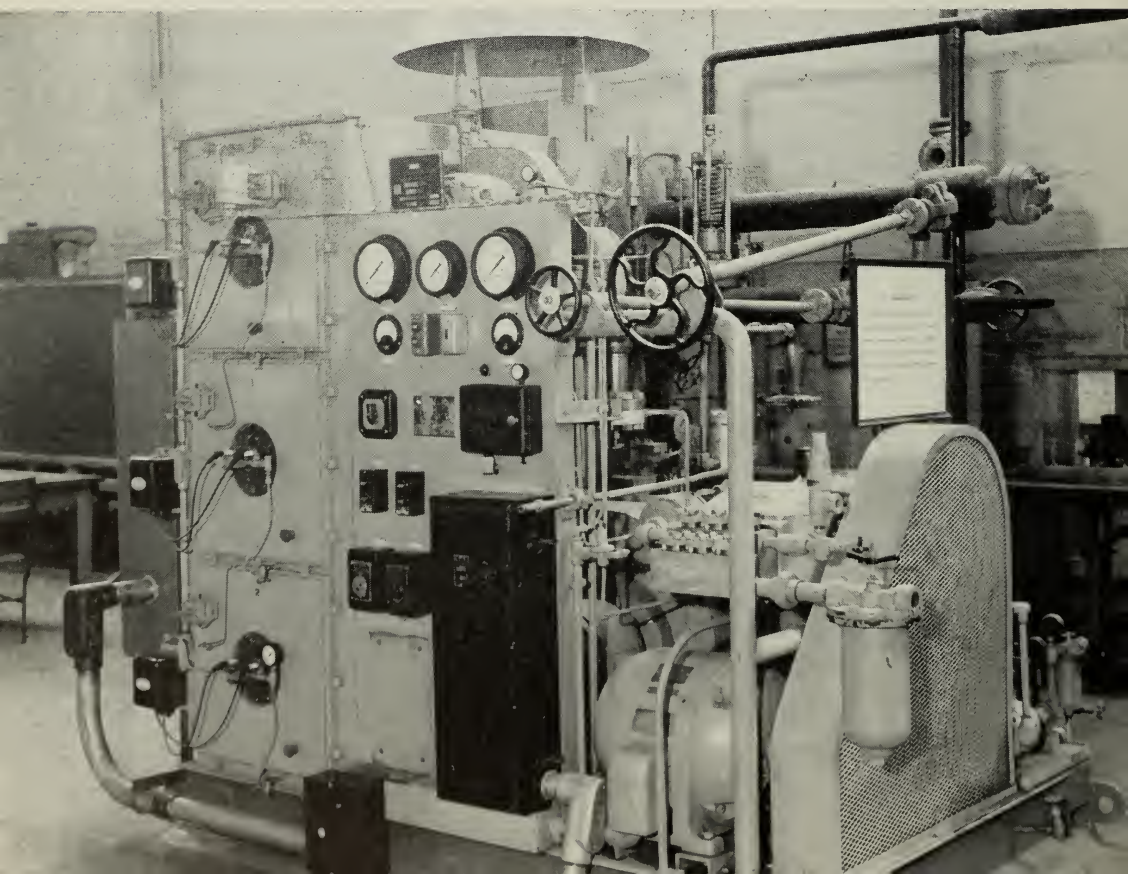
ratus in power-driven machines designed for, or adapted to, special industrial operations such as those found in mass production. This analysis includes not only the machine itself and its mechanisms and auxiliary apparatus and attachments, but also such items as tools, jigs, fixtures, etc. The material and final product studied with reference to the design or modification of new machines or apparatus, or the adaptability of existing machines or apparatus, to its production. Attention given to development of machines for mass production with particular reference to recent practice; effect of standardization and other factors that have influenced interchangeable manufacture and mass production.

443. Dynamics of Machinery. 1 unit; two one-hour periods and one three-hour period a week; first semester. *Prerequisite:* Undergraduate courses in Machine Design and Mechanics of Machinery. RYAN.

A course complementary to the undergraduate course and devoted to a more detailed study of velocities, acceleration, and forces in machine parts having reciprocating, rotating, and combined motions; balancing, critical speeds, and vibrations in shafts; gyroscopic action in machines; flywheels, governors; special topics. Topics include graphical vs. analytical methods; velocity, acceleration, and inertia force diagrams; Coriolis' law and applications.

HIGH-PRESSURE RESEARCH BOILER

Besler oil-fired steam generator capable of delivering 5,000 lbs. of steam per hour at 1,500 psig, 900° F. for high-pressure steam research.



444. Analytical Design of High-Speed Engines. 1 unit; two one-hour periods and one three-hour period a week; second semester. *Prerequisite:* Undergraduate courses in Machine Design and Mechanics of Machinery. BROGHAMER.

A study of the dynamics of high-speed engines with special reference to internal combustion engines, engine balance, crankshaft deflections, torsional vibrations. Topics include balancing of in-line, radial, and other types of engines; torsional vibrations in crankshafts and methods of damping; design analysis of crankshafts and crankshaft bearings; firing orders; analytical studies pertaining to design of cams, flywheels, and other parts; energy relations.

445. Design of Internal Combustion Engines. 1 unit; two three-hour periods a week; first semester. *Prerequisite:* Undergraduate courses in Mechanics of Machinery and Machine Design. HULL.

Detailed study of the design of the internal combustion engine; gas-pressure and inertia-force diagrams; determination of bearing loads; torsional vibration analysis; stress determinations and design of important parts, including piston, connecting rod, crankshaft, flywheel, valve mechanism, and cam layout.

446. Power Plant Design. 1 unit; three two-hour periods a week; second semester. *Prerequisite:* Undergraduate courses in Thermodynamics and Power Plant Design. SEYFARTH.

A design course covering the selection of equipment, and problems involved in the design and layout of a modern power plant. Topics include selection, performance characteristics, and integration of major and minor machinery in a steam power station; prevailing standards and procedures in power plant design.

448. Laboratory Investigation in Machine Design. ½ to 1½ units; one or more semesters; time to be arranged; first and second semesters. *Prerequisite:* Undergraduate courses in Machine Design and Mechanics of Machinery. STAFF.

Special investigations in machine design. Studies of some phase of mechanical transmission of power, including tests on belts, ropes, chains, gears, springs, clutches, couplings; wear and lubrication of bearings; vibration studies; static and dynamic balancing; force and stress analyses; photoelastic investigations. (See general notes on page 13.)

451. Metal Cutting. 1 unit; two two-hour periods a week; first semester. *Prerequisite:* Undergraduate courses in Advanced Metal Processing and either Heat Treatment of Metals or Physical Metallurgy. TRIGGER.

A study of the various factors involved in metal cutting and forming. Basic mechanics of machining processes including consideration of tool-chip friction and dynamic flow stress in the material. Study of the temperatures developed during cutting and forming; distribution and effect of temperatures upon the cutting or forming process. Heat balance in high-speed metal cutting and effects on tool life, surface finish, and dimensional accuracy of work.

453 (I.E.). Methods and Measurements of Industrial Work. 1 unit; three one-hour periods a week; first semester. *Prerequisite:* Undergraduate courses in Motion and Time Study, and Production Control.

Advanced theoretical analysis of factors affecting determination of economical methods, method standards, and time standards for industrial operations. Special investigations and term paper. Topics include development of economical method, including product design, tools, working conditions, process used, and quality level; establishment of method standard; time measurements of industrial work including machine work and operator performance; standard data to be observed and analyzed; time standards for indirect type operations.

454 (I.E.). Production Engineering. 1 unit; three one-hour periods a week; second semester. *Prerequisite:* Mechanical Engineering 453.

Advanced consideration of production engineering principles as related to cost analysis and reduction, control of flow of work in manufacture, evaluation of performance against standard and to compensation. Special investigations. Topics include structure of factory organization with emphasis on analyses and coordination of engineering functions; manufacturing costs as affected by sales forecast, standardization, tools and equipment used, engineering design, and alternate processes; estimating; evaluation of performance in terms of operator, the department, and the entire plant; materials control and scheduling of manufacturing operations, compensation of labor; application to departments other than production.

456. Measurement Standards. ½ unit; three one-hour periods a week; first semester. *Prerequisite:* Undergraduate courses in Tool Engineering and Metal Processing.

Precision measurements in the field of production engineering, including interference phenomena of light, dimensional measurements, physical standards of reference, gauges, surface measurements, and theory of the profilometer.

458. Laboratory Investigations in Production. ½ to 1½ units; one or more semesters; time to be arranged; first and second semesters. *Prerequisite:* Undergraduate courses in Metal Processing. STAFF.

Special problems and investigations in the field of production, particularly in materials processing, and production engineering. (See general notes on page 13.)

468. Laboratory Investigations in Railway Mechanical Engineering. ½ to 1½ units; one or more semesters; time to be arranged; first and second semesters. *Prerequisite:* Consent of instructor. SCHRADER.

Special investigations in field of railway mechanical engineering. Note: Analysis or experimental research in the field of railway mechanical engineering, such as determinations of stresses in car wheels, problems in stopping trains, dynamics of traction and effect on rails, use of dynamometer car for testing train resistance and tractive effort. (See general notes on page 13.)

478. Laboratory Investigations in Petroleum Production Engineering. ½ to 1½ units; one or more semesters; time to be arranged; first and second semesters. *Prerequisite:* Mechanical Engineering 371 or 372 or equivalent. LARSON.

Special investigations in field of petroleum production engineering. Note: Studies of some phase of behavior and properties of fluids in porous

media, recovery methods, well-drilling techniques, or storage and transportation of petroleum. (See general notes on page 13.)

491. Thesis. 1 to 2 units; time to be arranged; first or second semester. *Prerequisite:* Completion of at least three units of graduate studies. STAFF.

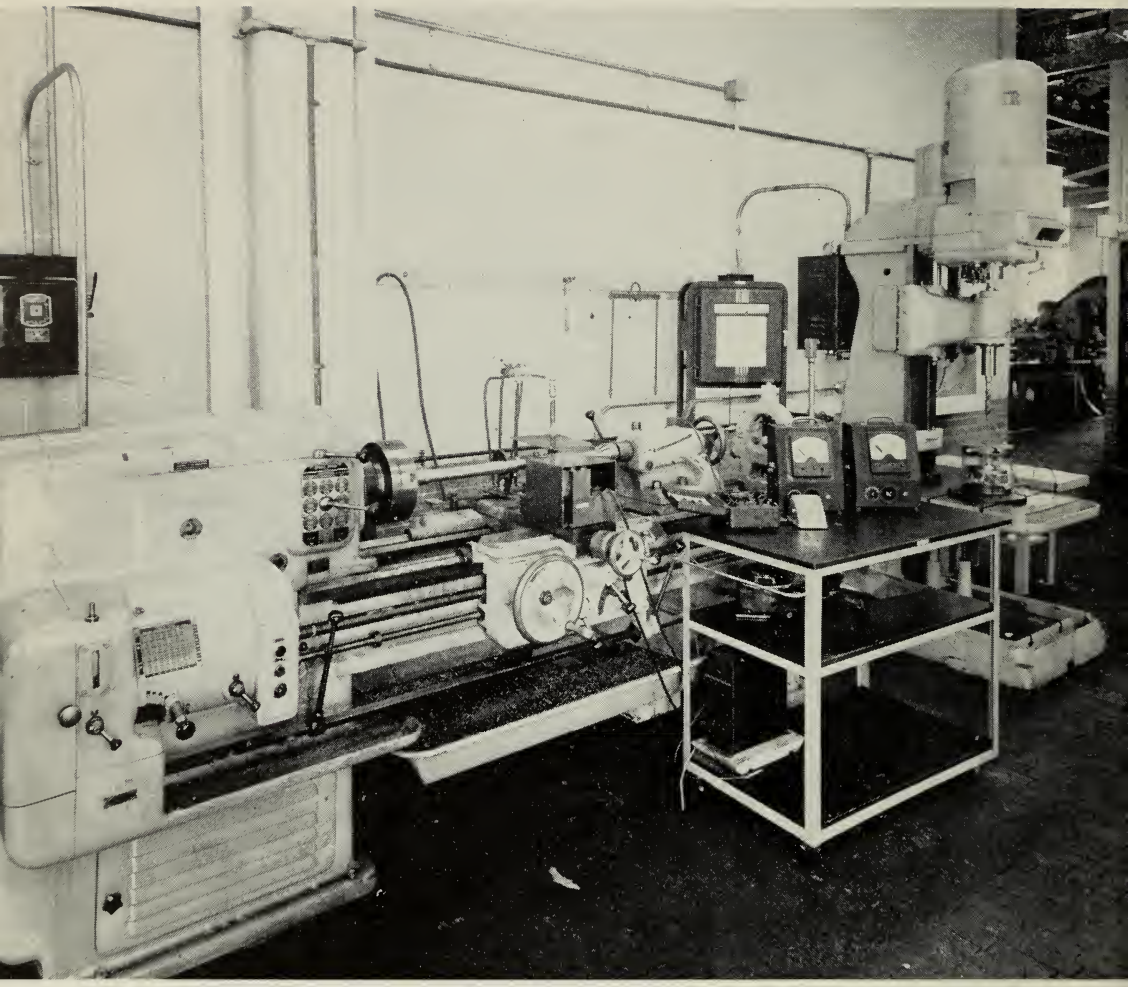
Note: A thesis will be required of all candidates for the degree of Master of Science in Mechanical Engineering, except under unusual circumstances and with the consent of the adviser. Eight units, including a thesis, will be considered as the minimum number leading toward the fulfillment of requirements. If a thesis is not submitted, a minimum of nine units will be required.

A thesis will be required of all candidates for a degree of Doctor of Philosophy in Engineering.

The topic for the thesis will be selected by the student in consultation with a member of the staff. "Instructions for the Preparation of Theses" may be obtained at the office of the Graduate College.

493. Graduate Seminar. No credit; one one-hour period a week; first and second semesters. *Prerequisite:* Graduate standing in mechanical engineering. KONZO.

Presentation and discussion of significant developments in mechanical engineering. One semester required of all mechanical engineering majors. Note: Students should register during the last semester of their work leading toward the Master of Science degree. Students will present reports either of their research studies or of some phase of mechanical engineering reported in technical literature.



METAL CUTTING RESEARCH EQUIPMENT

Heavy duty lathe equipped with tool force dynamometer and instrumented for measuring tool forces and temperatures. Drill press at the right is fitted with a strain gauge dynamometer for measuring torque and thrust during drilling or tapping operations.

SUGGESTED AREAS OF STUDY IN OTHER DEPARTMENTS

AERONAUTICAL ENGINEERING

Aerodynamics of Perfect Fluids
Indeterminate Aircraft Structures
Aircraft Power Plant Design
Analysis of Aircraft Shell Structures
Aerodynamics of Compressible Fluids
Aerodynamics of Real Fluids
Theory of Turbulence
Aerothermodynamics

CHEMICAL ENGINEERING

Unit Operations
Advanced Plant Design
Chemical Engineering Calculations
Distillation
Chemical Engineering Thermodynamics
Power Plant and Boiler Water Problems
Heat Transmission

CIVIL ENGINEERING

Hydrology and Flood Control
Water Power Engineering
Buckling, Vibrations, and Impact
Behavior of Structures Under Dynamic Loads
Numerical and Approximate Methods of Structural Analysis
Soil Mechanics
Structural Theory of Design
Design of Plates and Slabs
Statically Indeterminate Structures

ELECTRICAL ENGINEERING

Engineering Analysis
Engineering Measurements
Servomechanisms and Automatic Control Devices
Nonlinear Oscillating Systems
Acoustics

MATHEMATICS

Differential Equations and Orthogonal Functions
Vector and Tensor Analysis
Partial Differential Equations
Introduction to Numerical Methods

Statistics
Advanced Calculus
Real and Complex Variables
High-Speed Computing
Laplace Transformations
Mathematical Methods in Engineering and Science

METALLURGICAL ENGINEERING

Metallurgy of Welding
Metallurgy of Steel Casting
Physical Metallurgy
Tool Steels and Related Alloys
Metallurgical Kinetics and Thermodynamics
Powder Metallurgy
Physics of Metals
Metallography
Stainless Steels and High Temperature Alloys

PHYSICS

Kinetic Theory of Gases
Light
Radioactivity and Nuclear Physics
Dynamics
Sound
Statistical Mechanics
Atomic Physics

THEORETICAL AND APPLIED MECHANICS

Mechanical Vibrations
Fluid Mechanics and Advanced Hydraulics
Properties of Engineering Materials
Dimensional Analysis and Theory of Models
Experimental Stress Analysis
Vibration Analysis
Mechanics of Materials
Applied Fluid Mechanics
Theory of Flow of Incompressible Fluids
Theory of Elasticity

HOUSING

The University operates apartment buildings and some temporary houses. For information about these facilities, write to the Housing Division, University of Illinois, Illini Hall, Champaign, Illinois.